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# DEVELOPMENT, FECUNDITY, AND LONGEVITY OF THE COTTON LEAFPERFORATOR IN RELATION TO TEMPERATURE

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Western Region

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U.S. DEPARTMENT OF AGRICULTURE

In Cooperation With

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# DEVELOPMENT, FECUNDITY, AND LONGEVITY OF THE COTTON LEAFPERFORATOR IN RELATION TO TEMPERATURE

R. E. Fye and C. J. May[1]

## INTRODUCTION

Introduction and manipulation of general predators for the control of a specific species of pest may be seriously hampered by the presence of a large, alternate food source for the predator. In Arizona, the cotton leafperforator, *Bucculatrix thurberiella* Busck, is not only a localized pest (*8*, *9*, *10*)[2] in some growing seasons, but is a large food source for predators (*10*) late in the growing season. The basic life cycle, recently discussed by Watson and Johnson (*11*), starts with the female moth laying eggs on the surface of the leaf. When the egg hatches, the small larvae enter the leaf and pass the first three instars as leaf miners. The larvae then emerge from the mine and feed freely during the fourth instar, after which a web is formed and the larvae forms the so-called horseshoe stage where the molt to the fifth instar occurs. The larva emerges from the web and feeds freely on the surface of the leaf, and when larvae occur in large numbers, whole leaves are skeletonized. The pupal cocoon is formed on a roughened surface and, subsequently, the adult emerges from the small, tough cocoon.

The following study was made to develop a predictive method to forecast when large numbers of the cotton leafperforator could be expected as a competing food source of the predators and to determine the reproductive potential so that the numbers of the perforators could be estimated.

## METHODS

Adult cotton leafperforators for the biological study were obtained from a culture maintained on cotton plants in a greenhouse where light and temperature regimes simulated late summer days. The culture was initiated from pupae collected in the fall of 1971, and the study was made during the winter and spring of 1971-72.

An oviposition cage, consisting of a pasteboard carton (about 1ft$^3$) with a nylon organdy top, was maintained in the greenhouse. Adults from the culture were introduced at various intervals to maintain a strong ovipositing population in the oviposition cage so that a large supply of eggs was readily available. Individual cages used in the study of the development and fecundity consisted of 1.5-oz plastic creamer cups closed with polyethylene snap-top lids through which a 6-dr glass vial could be inserted (fig. 1). The bottom of the creamer cup was opened and re-covered with a nylon net to provide ventilation. The 6-dr vial filled with nutrient solution provided a container for a seedling cotton plant that provided foliage for the development and oviposition of the confined perforator moths.

The vial portions of the cages described above were placed in the oviposition cage in the greenhouse to obtain eggs on the seedlings. After 24 hours, the seedlings were removed and placed in the desired constant or programed temperature regime. The seedlings were inspected daily

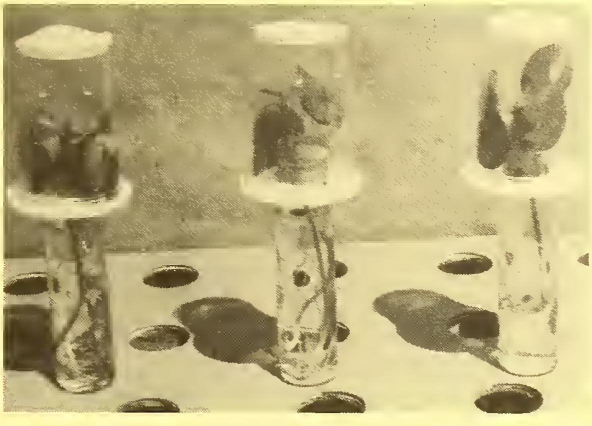

FIGURE 1.—Cages used for study of individuals and pairs of the cotton leafperforator.

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[2] Italic numbers in parentheses refer to Literature Cited, p. 5.

to determine when mines of the perforator were initiated, and each mine was numbered with a felt tip marker. As the larvae emerged from the mines, each was removed to a cotton seedling in an individual cage. The cages were inspected daily, and the progress of the leafperforators through the fourth instar, including the horseshoe stage, the fifth instar, the pupal stage, and into adulthood, was noted, and the period in each stage recorded. When the adults emerged, the perforators were sexed, paired, and introduced into similar individual cages. At 3-day intervals, the pairs were moved to a new seedling, and the previously exposed seedlings were held in the same temperature regime to determine the effective fecundity of the individual females. The effective fecundity was determined from the number of mines initiated by the larvae during the first instar. The transfer procedure was continued at 3-day intervals until the deaths of both adults. From these data, the length of the various stages and the preoviposition period, the oviposition pattern in time, and the longevity and fecundity of the perforators were determined.

The temperatures for the study included constant regimes of 20°, 25°, 30°, and 35° C with humidity ranging from 30 percent at the higher temperatures to 50 percent at the lower temperatures and the photoperiod of 12 hours light under fluorescent lamps. The programed regime, ranging from 10° to 27.2° with a mean of 21°, was repeated daily in an environmental chamber with a photoperiod similar to the constant temperature regimes. For the greenhouse study, a photoperiod of 12:12 and temperatures ranging from 15° to 35° were employed to simulate late summer days with variable temperatures.

## RESULTS AND DISCUSSION

The developmental periods for the egg, larval, and pupal stages are shown in table 1. The egg stage ranged from 3.8±0.1 days at 35° C to 9.2±0.5 days for the females in the 20° regime. The larval-pupal period ranged from 9.9±0.7 days at 35° to 26.0±1.0 days at 20°. Periods for egg, larval, and pupal development were similar for males and females.

Figure 2 presents regression lines for determination of reciprocal units of development (*5*, *6*). The reciprocal units of development (RUD) for the regression lines are determined by dividing the number of 2-hour periods in the developmental stage at the successive constant temperatures into 1, that is, the total development. The RUD are then graphed with log temperature in degrees Centigrade as the independent variable. Thus, the RUD are the proportion of development in a 2-hour period at a given temperature. The regression lines provide a means of directly determining the RUD. The regression equation for the eggs of the cotton leafperforator is:

$$\hat{y} = -0.6143 + 0.0540 \log t$$

where $\hat{y}$=the estimate of RUD during a given 2-hour period, and t=log mean temperature of the substrate during the 2-hour period. The larval-pupal RUD may be best determined directly from the regression line presented in figure 2.

Summation of the RUD for each 2 hours in a temperature regimen yields an estimate of the age stratification of the population exemplified by the RUD in the constant temperature of 30° C (table 2). Similar tabulations of the age stratification in other constant temperature regimes generally show a close relationship between the accumulated RUD and the age stratification regardless of the temperature tested (within the range of temperatures associated with the full physiological responses). When the summation of the RUD associated with the larval-pupal period totals 1, 50 percent of the adult population from eggs produced on a given prior day should have emerged (table 2).

In the programed regime with a mean temperature of 21° C, the summation of the RUD for the eggs ranged from 0.9072 to 1.1350 with a mean of 0.9720 and for the larval-pupal stage from 0.9429 to 1.5266 with a mean of 1.1191. In the greenhouse, the summation of the RUD for the eggs ranged from the extremes of 0.8343 to 1.1832 with a mean of 1.0544, and for the larval-pupal period from 0.9481 to 1.1973 with a mean of 1.0227. Thus, the RUD in the programed and greenhouse regimes yielded relatively good estimates of the

*TABLE 1.—Developmental periods*[1] *for the cotton leafperforator,* Bucculatrix thurberiella *Busck.*

| Temperature (° C) | Sex[2] | Egg | | Mining stages | | 4th-instar feeding | | Horseshoe | | 5th-instar | | Pupal | | Total larval-pupal | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Constant: | | | | | | | | | | | | | | | |
| | | *No.* | *Days* | *No.* | *Days* | *No.* | *Days* | *No.* | *Days* | *No.* | *Days* | *No.* | *Days* | *No.* | *Days* |
| 20° | M | 53 | 8.9±0.2 | 53 | 6.8±0.4 | 52 | 1.5±0.5 | 51 | 1.2±0.3 | 50 | 2.8±0.6 | 46 | 13.7±0.5 | 46 | 26.4±0.9 |
| | F | 54 | 9.2±0.5 | 54 | 7.1±0.3 | 54 | 1.5±0.5 | 54 | 1.2±0.3 | 53 | 2.8±0.4 | 51 | 12.8±0.7 | 51 | 25.5±1.1 |
| 25° | M | 48 | 6.3±0.7 | 48 | 4.2±0.8 | 48 | 1.0±0.1 | 47 | 0.7±0.1 | 47 | 2.0±0.5 | 45 | 6.4±0.4 | 44 | 14.6±0.8 |
| | F | 51 | 6.3±0.6 | 51 | 4.2±0.6 | 50 | 1.1±0.3 | 50 | 0.9±0.3 | 49 | 2.0±0.4 | 47 | 6.1±0.8 | 46 | 14.4±1.1 |
| 30° | M | 45 | 4.4±0.4 | 45 | 2.3±0.4 | 45 | 1.0±0.1 | 44 | 0.8±0.2 | 42 | 1.7±0.5 | 38 | 4.4±0.4 | 38 | 10.4±0.7 |
| | F | 64 | 4.5±0.4 | 63 | 2.6±0.5 | 63 | 0.9±0.1 | 63 | 0.8±0.3 | 59 | 1.6±0.5 | 56 | 4.3±0 4 | 56 | 10.3±0.9 |
| 35° | M | 48 | 3.9±0.2 | 48 | 2.0±0.1 | 48 | 1.3±0.4 | 48 | 0.7±0.2 | 43 | 1.8±0.4 | 41 | 4.0±0.1 | 33 | 9.9±0.7 |
| | F | 48 | 3.8±0.1 | 48 | 2.0±0.1 | 47 | 1.6±0.4 | 47 | 0.7±0.3 | 43 | 1.8±0.3 | 34 | 3.9±0.2 | 36 | 10.0±0.6 |
| Greenhouse (15° to 35°) | M | 56 | 6.4±0.5 | 56 | 5.2±0.4 | 56 | 1.2±0.5 | 56 | 0.8±0.2 | 53 | 2.3±0.4 | 49 | 6.2±0.4 | 51 | 16.0±0.8 |
| | F | 49 | 6.2±0.5 | 48 | 5.3±0.4 | 49 | 1.5±0.6 | 49 | 0.7±0.3 | 48 | 2.1±0.4 | 47 | 6.0±0.1 | 48 | 16.1±0.9 |
| Programed (21°) | M | 44 | 8.4±0.4 | 44 | 6.9±0.6 | 44 | 1.5±0.4 | 44 | 1.0±0.3 | 43 | 2.7±0.6 | 43 | 13.2±0.8 | 44 | 25.1±1.3 |
| | F | 54 | 8.5±0.5 | 54 | 6.7±0.7 | 54 | 1.3±0 5 | 54 | 1.1±0.3 | 54 | 2.6±0.6 | 54 | 12.8±1.2 | 54 | 24.6±1.3 |

[1] Stages as per Watson and Johnson (*11*).

[2] M, male; F, female.

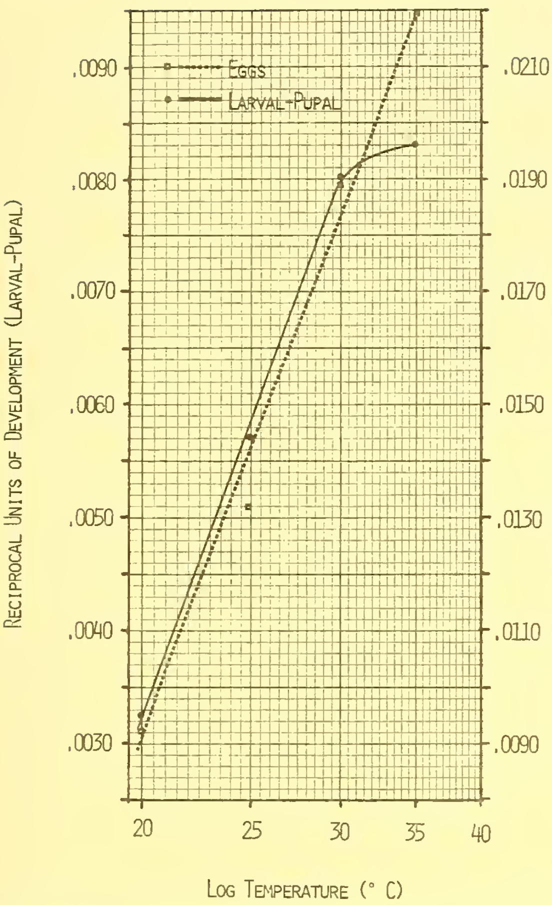

FIGURE 2.—Regression lines for estimating reciprocal units of development for 2-hour periods from the log temperature.

development of the individuals of the cotton leafperforator although the larval-pupal period was slightly underestimated in the 21° regime. The accuracy of the developmental estimates may also be noted in the representative data in table 2 that is concerned with a constant temperature of 30°. The accuracy may be partially attributed to the inclusion of these data in the calculation of the regression lines.

Table 3 contains data on the preoviposition period, which in the majority of cases was from 1 to 3 days, although a few individuals had a longer preoviposition period. The preoviposition data in table 3 and the oviposition pattern data in table 4 indicate that the preoviposition period is usually relatively short and that large segments of the potential egg production are deposited during early adulthood. A few individuals may oviposit for periods up to 4 weeks, particularly when the temperatures are low.

The longevity and fecundity data in table 5 demonstrate a decreasing longevity and fecundity in the constant temperature regimes as the temperatures increase. In fact, females reared at a constant 35° C were short lived and laid no eggs. These data parallel the data previously presented by Fye and Poole (*7*) and Fye and McAda (*6*) for six other species of Lepidoptera attacking cotton in Arizona. The longevity of the male moths and the fecundity in the programed 21° regime closely approximated the constant 25° data although the females in the 21° programed regime lived nearly twice as long. The longevity of the individuals in the greenhouse study fell midway between the individuals in the 20° and 25° constant regimes; however, the fecundity more closely approached the fecundity of the females in the constant 20°. Although the daily maximum temperatures included in the greenhouse regime were relatively high, the higher

*TABLE 2.—Percentage of living cotton leafperforators in the designated larval instar, pupal, or adult stage on a specific day when reared in a constant temperature of 30° C*

| Day | RUD[1] | Percentage of insects in indicated stage | | | | |
|---|---|---|---|---|---|---|
| | | Larval instar | | | | |
| | | 1st to 3rd | 4th | 5th | Pupal | Adult |
| 1 | 0.0960 | 100.0 | | | | |
| 2 | | 100.0 | | | | |
| 3 | .2880 | 54.8 | 45.2 | | | |
| 4 | | | 80.6 | 19.3 | | |
| 5 | .4800 | | 19.3 | 78.5 | 2.2 | |
| 6 | | | 1.0 | 61.3 | 37.6 | |
| 7 | .6720 | | | 11.8 | 88.2 | |
| 8 | | | | 1.0 | 99.0 | |
| 9 | .8640 | | | | 99.0 | 1.0 |
| 10 | | | | | 75.0 | 25.0 |
| 11 | 1.0560 | | | | 39.7 | 60.3 |
| 12 | | | | | 28.6 | 71.4 |
| 13 | 1.2480 | | | | | 100.0 |

[1] Reciprocal units of development.

*TABLE 3.—Percentage of female cotton leafperforators initiating oviposition in several temperature regimes*

| Days | Temperature | | | | | |
|---|---|---|---|---|---|---|
| | Constant | | | | Programed | Greenhouse |
| | 20° C | 25° C | 30° C | 35° C | (21° C) | (15° to 35° C) |
| 1-3 | 75.8 | 87.2 | 20.0 | 0 | 77.1 | 84.8 |
| 4-6 | 6.0 | 2.4 | 2.9 | 0 | 2.9 | 9.1 |
| 7-9 | 3.0 | 0 | 0 | 0 | 0 | 0 |

*TABLE 4.—Percentage of eggs laid by a population of cotton leafperforators*

| Days after emergence | Temperature | | | | | |
|---|---|---|---|---|---|---|
| | Constant | | | | Programed | Green-house (15° to 35° C) |
| | 20° C | 25° C | 30° C | 35° C | (21° C) | |
| 1-3 | 24.9 | 72.4 | 59.6 | 0 | 51.2 | 36.6 |
| 4-6 | 17.4 | 17.4 | 33.6 | 0 | 21.8 | 21.0 |
| 7-9 | 22.1 | 9.5 | 6.7 | 0 | 10.1 | 17.9 |
| 10-12 | 16.7 | 0.7 | 0 | | 10.8 | 13.1 |
| 13-15 | 10.4 | 0 | | | 4.9 | 7.0 |
| 16-18 | 5.2 | | | | 1.1 | 3.1 |
| 19-21 | 2.2 | | | | 0 | 1.3 |
| 22-24 | 0.8 | | | | | 0 |
| 25-27 | 0.3 | | | | | |
| 28-30 | 0 | | | | | |

*TABLE 5.—Longevity and fecundity of cotton leafperforators*

| Temperature (° C) | Longevity in days ± SD | | Fecundity (number of eggs ± SD) |
|---|---|---|---|
| | Male | Female | |
| Constant: | | | |
| 20 | 20.7±7.8 | 20.2±10.3 | 93.2±64.8 |
| 25 | 7.0±2.6 | 7.9± 3.0 | 44.6±32.5 |
| 30 | 5.8±2.9 | 7.3± 3.8 | 7.1±18.9 |
| 35 | 3.6±1.4 | 4.6± 1.7 | 0 0 |
| Programed: | | | |
| 21 | 7.5±3.0 | 13.2± 7.5 | 42.1±34.8 |
| Greenhouse: | | | |
| 15 to 35 | 11.5±6.5 | 15.1± 7.2 | 100.2±55.0 |

relative humidity in the greenhouse apparently had a marked favorable effect on the fecundity. This phenomenon has been suggested for the bollworm, *Heliothis zea* (Boddie), and for the cabbage looper, *Trichoplusia ni* (Hübner), by Ellington (*2*) who found that the fecundity is drastically reduced by low humidities and that in high humidities the potential of the ovipositing females is better achieved. The relatively low fecundity in the 21° programed regimes may have been partially due to the constant disturbance of the ovipositing females observed during the rapid air movement within the study cabinet.

The mortality data in table 6 indicate that the majority of the moths die shortly after oviposition is completed, but a few survive for extended periods. The longevity data compare favorably with that of Watson and Johnson (*11*) although the longevity in the 20° C constant regime in this study was appreciably longer (about 20 days) as compared to a longevity of 8 to 11 days noted by Watson and Johnson (*11*).

The egg stage of 3.9 days, presented in table 1 for a constant temperature of 35° C, compares favorably with the 4.5-day, 3.2- to 4-day, and 3.19-day egg stages of Tuttle and others (*10*), Stevenson and Kauffman (*8*), and Watson and Johnson (*11*), respectively. The slightly longer period reported by Tuttle and others (*10*) suggests that the high temperatures (daily mean maximums of 104° F and daily mean temperatures of 90° F or more) might have had some deleterious effect upon the eggs which is also suggested by the greenhouse study presented in table 1. Likewise, the data presented for the larval development in table 1 are in general agreement with the periods reported by Tuttle and others (*10*), Stevenson and Kauffman (*8*), and Watson and Johnson (*11.*)

The pupal period of 3 to 4 days at temperatures of 30° and 35° C as presented in table 1 is slightly shorter than the 5- to 8-day figures of Tuttle and others (*10*), Stevenson and Kauffman (*8*), and Watson and Johnson (*11*). However, since the data of the previous authors (except Watson and Johnson (*11*)) for the Arizona strain of the cotton leafperforator were a composite from outdoor temperatures, the 25° C and the greenhouse study figures in table 1 are probably more comparable and are in agreement with the previous work. The overall period of 17 days reported by Tuttle and others (*10*) and the developmental periods of Watson and Johnson (*11*) are also comparable to the data presented in table 1. Likewise, Folsom (*3*) indicated that the mean overall development period from egg to adult was 18 days in the Imperial Valley of California, and this too is in agreement with the data in table 1.

The fecundity data in table 5 agree with that of Watson and Johnson (*11*) only in the 25° C constant temperature regime and in the programed regime of 21° C that is comparable to the 91° to 57° F regime of Watson and Johnson (*11*). In the 20° C constant regime, the fecundity in our test was more than four times the 21-egg mean reported by Watson and Johnson (*11*). In the greenhouse, where the regimes were roughly similar, the fecundity was almost double. In the 30° and 35° C regimes the fecundity reported by Watson and Johnson (*11*) was considerably greater than that determined in our tests. The mean fecundity and the confidence limit for the 30° C constant regime would indicate that some individuals in our tests oviposited numbers of eggs similar to those studied by Watson and Johnson (*11*). However, at 35° C the fecundity was reduced to zero. This agrees with the developmental data, which indicate that a maximum larval-pupal development is attained somewhere near this temperature. Therefore, the data suggest a maximum developmental and physiological rate at temperatures of 30° to 33° C.

*TABLE 6.—Percent mortality of cotton leafperforators for 3-day intervals*

| Days after emergence | Constant temperatures | | | | | | | | Fluctuating regimes | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 20° C | | 25° C | | 30° C | | 35° C | | Programed (21° C) | | Greenhouse (15° to 35° C) | |
| | Male | Female | Male | Female | Male | Female | Male | Female | Male | Female | Male | Female |
| 1-3 | 0 | 2.9 | 5 | 7.7 | 11.3 | 8.6 | 54.2 | 27.3 | 5.6 | 0 | 2.8 | 0 |
| 4-6 | 2.8 | 11.4 | 51.3 | 38.3 | 63.0 | 48.4 | 42.6 | 45.3 | 43.0 | 8.6 | 17.8 | 6.1 |
| 7-9 | 9.0 | 2.7 | 23.2 | 25.8 | 14.3 | 20.0 | 3.2 | 27.4 | 42.7 | 34.3 | 41.2 | 27.2 |
| 10-12 | 2.8 | 8.6 | 15.4 | 25.5 | 5.7 | 14.3 | - | - | 3.0 | 17.1 | 5.7 | 15.2 |
| 13-15 | 8.8 | 3.0 | 5.1 | 0 | 2.7 | 2.0 | - | - | 0 | 8.6 | 11.8 | 12.0 |
| 16-18 | 11.9 | 11.3 | - | 2.7 | 3.0 | 1.7 | - | - | 5.7 | 11.4 | 6.0 | 9.2 |
| 19-21 | 17.5 | 20.1 | - | - | - | 3.0 | - | - | - | 5.6 | 5.9 | 9.2 |
| 22-24 | 14.7 | 2.7 | - | - | - | - | - | - | - | 3.0 | 0 | 5.8 |
| 25-27 | 11.8 | 14.3 | - | - | - | - | - | - | - | 0 | 2.8 | 9.1 |
| 28-30 | 8.9 | 5.8 | - | - | - | - | - | - | - | 5.7 | 6.0 | 3.2 |
| 31-36 | 12.1 | 11.5 | - | - | - | - | - | - | - | 5.7 | - | 3.0 |
| 37-39 | - | 0 | - | - | - | - | - | - | - | - | - | - |
| 40-43 | - | 5.7 | - | - | - | - | - | - | - | - | - | - |

## CONCLUSIONS

The results presented in this report indicate that the cotton leafperforator is a warm—not hot—weather insect. In sustained high temperature regimes, the fecundity of the females was drastically reduced. The data present a partial explanation for the late-season development of large populations of the cotton leafperforator in Arizona. In the latter part of the growing season, slightly declining temperatures due to seasonal changes are accentuated by shading within the cotton canopy (Fye and Carranza (*4*)) and higher relative humidity. With these modifications by the plant canopy and improved oviposition conditions, the females are better able to approach their full ovipositional potential. Thus, with an improved oviposition level and an ideal developmental temperature situation (table 1), the population is able to escape the suppressive bioclimate of early to midseason. The combination of improved developmental conditions, increased competition for predation, and a declining predator population (Bryan and others (*1*)) probably lead to an increase in the late-season populations of the cotton leafperforator and other Lepidoptera associated with cotton.

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